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Introduction

The environmental risks associated with the strong development of livestock commodity chains in Southeast Asia are mainly the consequence of mismanagement of animal excreta, leading to pollution of surface water, underground water and soil by nutrients, organic matter and heavy metals. Vietnam is one of the countries in Asia where very high surpluses of nutrients are observed. Taking phosphorus as an indicator, these surpluses are more than 20 kg per ha of agricultural land or even double that amount in some areas (1). In addition, in the Red River Delta, animal production is experiencing strong growth. Between 1990 and 1994, the value of total rice production rose at an average rate of 6% yearly. During the same period, pig production showed an average annual growth, in value, of 6.75% (2).

It is interesting to focus on the consequences of these current developments on the quality of the environment: for every increase in livestock production, an increase in the stock of livestock effluents to be managed must be associated with it. The European experience has shown the possible ill effects of a massive increase in livestock farms. Appropriate management of livestock effluents is vital.

No previous study makes it possible to give an opinion on the pollution currently caused by livestock effluents in Thai Binh province, nor in the Red River Delta. These threats are however indispensable factors to be taken into account with a view to sustainable development of livestock commodity chains. The idea here is to quantify the supply (production of farm fertilizer), the requirements (needs of crops and ponds) in livestock effluents, possible transfers and to assess the adequacy, or in other words the mass balance, between the sources of production and the potential consumption areas. There are several methods of calculating mass balances of mineral elements on various scales. These tools aim to characterize a real situation, via the calculation of "inputs-outputs" balances, in order to deduce possible pollution caused by the system in question. The existing bibliography is large and relatively recent on nutrient mass balances. Depending on situations, the FAO presents several approaches and methods that have been used for these evaluations (3). There are methods suitable for each of the micro levels (plot, farm), meso (region, agro-ecological area), macro (state, continent, world), for which we quote a few examples below:

- Micro: NUTMON (Nutrient Monitoring) which enables (i) monitoring of nutrients in tropical agricultural systems, (ii) analysis of the financial and environmental sustainability of systems. Diagnosis environment of the livestock farm (Dexel) in France.
- Meso: Stoorvogel and Smaling Method, 1990 and the French methods of the IFEN and the SCEES.
- Macro: Stoorvogel and Smaling Method, 1990. The IFDC approach that draws on previous works by using the characteristics of GIS conjointly with the methods and procedures enabling an estimation of mass balances. At the national level, the OCDE approach.

All these approaches are based on short time lapses (season, crop cycles, year) and rely on numerous hypotheses relative to the dynamic of nutrients in the soil, on their efficiency of use by plants, etc. Today, these mass balances are considered as indicators of the sustainability of agricultural systems and they are useful for drawing up strategies for nutrient management. Here, the objective is to compare a real production of livestock farm effluents with potential uses of these effluents, which are in the hypothetical domain. Knowledge of the quantities of mineral fertilizer really used is not useful in our study, while it is a determining factor in the abovementioned methods. These methods did not seem appropriate for the aims and the context of the study (the necessary transposition of French abacuses into a subtropical environment in particular posed a problem).

After having presented the statistical data used for the calculation of the characterization of existing effluent products, crops and ponds we will present the methods and hypotheses for calculation of quantities of farm fertilizer potentially usable by the consumption areas that are crops and fish farm ponds. For the calculation of mass balances (adequacy between supply and demand), we will present the implementation of the three scenarios selected, a current scenario in 2005 and two prospective scenarios in 2010, following an approach based on the current usage practices for farm fertilizers and following an approach based on a "reasoned" practice of fertilization. Then, we will present the results of estimation of the farm fertilizer stock produced in the province and the results of calculations of mass balances obtained according to the three scenarios, emphasizing the results given by the approach based on the current usage practices of farm fertilizer. Finally, we will discuss the results, their interest, their limits and perspectives for improvement in association with the local stakeholders.

Material and methods

It was therefore necessary to establish an original approach that was suited to the issues encountered in Thai Binh province. We met with several constraints, in particular the lack of local data on farm fertilizers and the scant contact established with the local agricultural offices. Finally, one of the objectives of this work was the construction of a genuine tool making it possible to calculate balances in livestock effluents, and to be reusable afterwards by the Vietnamese partners.

Establishing a set of statistical data

The quality of available statistical data is one of the key factors for any quantitative study of this kind at the regional level: they condition the usable modes of calculation, the number of hypotheses to be formulated, and the pertinence of the results obtained. The idea is to acquire data making it possible in fine to quantify at the communal level the production of farm fertilizers on one hand, and the quantity of these fertilizers potentially usable in the various consumption areas on the other. The elements quoted in the presentation of the agricultural context make it possible to identify the sources and the potential consumption areas for farm fertilizer. The sources of effluents are pig, cattle and water buffalo herds, and poultry flocks. Human excreta are also taken into account. The potential consumption areas are i) perennial and annual crops; ii) fishponds and iii) gardens, consisting mainly of fruit trees and medicinal trees (see Chapter 8)

The first singularity observed in the collection of statistical information is that there is no farm-by-farm census in Vietnam: the data concerning livestock farming, crops and fishponds are collected separately. The census of animal herds is done by direct counting on the farm twice yearly, and is organized by the district statistical office that sends representatives into the villages. Cultivated areas are declared by the farmers to the communal or village co-operative, at the beginning of each season. Finally the ponds are measured and counted in the field by agents of the land registry, during communal data collection campaigns. The Provincial Statistics Office and Agricultural Office centralize all this information via the district agricultural and statistics offices (4).

Existing agricultural data are therefore only available at the communal level. The assessment of the pig herd at communal level is therefore a moot point. At the time of the agricultural census, the technicians count the number of mature sows and boars weighing over 25 kg on the farm that day. In fact, the occupation rate of pig sheds can vary quickly in local production systems. Figure 11 in Chapter 2 illustrates the various existing flows of live pigs (sale-purchase) both at the farm and the communal level. The pigs can be sold very young, or after six months of fattening, depending on their destination. The opportunist strategy developed by small-scale and medium-sized producers, who constantly adapt their purchases and sales of piglets/pigs to the market price, makes any truly “realist” census difficult. We therefore observe more or less important variations between successive censuses (for example, a difference of 50,000 pigs between the censuses of August 2004, then of April and August of 2005 in Vu Thu district). This is why we have chosen to estimate the pig herd from the number of sows counted in the communes, which is more stable over time (it progresses regularly from one census to another). Two hypotheses can be formulated from this, which will be taken up again later: i) all pigs born in a commune are fattened in this same commune, and ii) the piglet input flow is compensated by the flow of outputs.

Modelling of the study area

The study area covers the whole of Thai Binh province divided administratively into eight districts, themselves divided into 285 communes. The objective of this study is to determine what is the relationship between the quantity of farm fertilizer produced in this area and its capacity to reabsorb this organic matter. We are building a “logical framework” here, by defining various components (livestock operation, potential consumption areas and farm fertilizers), regulated by local practices and management of livestock effluents (see Chapter 5). This framework incorporates the available statistical data, and thus makes it possible to calculate the balance of farm fertilizer.

To specify the scale in spatial terms, we have decided to calculate the balance between production and potential use of farm fertilizers at the communal level for the following reasons:

– The commune in the basic administrative unit as far as planning is concerned; for example, the specialization of communes programmed by seven of the province’s eight districts
– All Vietnamese agricultural census data is at the communal level
– In cases of local surpluses, it appears interesting to envisage inter-communal farm fertilizer transfers, the distances in question being reasonable given

the poor quality of roads in the rural areas. In addition, these kinds of transfer already exist within the study area (see Chapters 5 and 9).

The commune must therefore be modelled despite the fact that the available statistical data does not make it possible to make a calculation based on the structural data concerning farms in the district. We will therefore consider each commune as if it were a single, whole farm, incorporating various production operations. The size of the latter (herds and acreage cultivated) is determined from statistics collected at the communal level. This model was developed in two stages:

Stage 1: model of the farm - The aim of this first step is to represent all flows of material (including farm fertilizers) that might exist on a theoretical local farm, which would incorporate an array of production operations. The elements given in the description of the agricultural context and the associated livestock effluents issue (see Chapters 2 and 5) makes it possible to understand these transfers, typical of integrated systems. Figure 1 (in Chapter 5) illustrates these effluent transfers from producing operations towards consuming operations both precisely and exhaustively. The diagram given does not specify the kind of farm fertilizer produced, because it varies from farm to farm. It is necessary therefore to define a "medium-sized" farm, and to specify the rules according to which farm fertilizers are managed there.

Stage 2: model of the commune - The transposition of the model of the farm to the scale of the commune requires the formulation of hypotheses aimed at characterizing:

1. The practices of collection/evacuation; which make it possible, whatever the kind of farm, to collect all solid excreta (scraping or collection in the field), including human excreta. Liquid excreta and cleaning water are only recycled on pig farms equipped for storage and in some dwellings that collect human urine.
2. Storage/processing practices; which consist for solid excreta in storage associated with a systematic composting with plant waste (water hyacinths) or remnants from crop harvesting (rice stalks) and the ashes of rice stalks when it is human excreta.
3. Use/transfer practices; which associate effluent-crop couples and the arbitration rules for allocation of effluents to crops. Composts are generally spread on annual crops. Perennial crops (for example silkworm farming) are only fertilized with composts from pigs or cows. Liquid excreta and cleaning water are used to fertilize the family garden featuring "bucket-watered" fruit trees.

In the case of associating raising ducks, chickens, pigs and cows with fish farming, we will consider that all effluents flow directly into the pond. Pig slurry is no longer scraped. This corresponds to the VAC system's configuration: the animal shelters are positioned over or on the edge of the pond.

Finally, the choice of this communal model calls for the formulation of other, more implicit hypotheses: i) the entire cultivated area can receive farm fertilizers, i.e. is "spreadable"; ii) all gardens can be fertilized with liquid pig effluents, and iii) all ponds can be associated with duck, chicken or pig farms. All of these hypotheses make it possible to define a model, illustrated in Figure 2. The rest of the study will be built up from this diagram. It defines a framework that makes it possible to quantify supply and demand of farm fertilizers in communes.

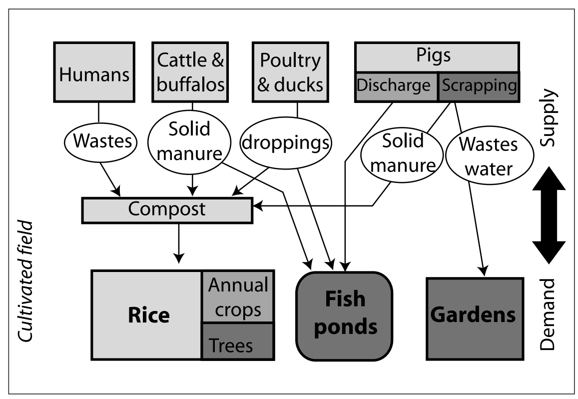

Figure 1: *Model of the commune and flows of livestock effluents (AP: annual plants other than rice, PP: perennial plants)*

Characterization of farm fertilizers produced in Thai Binh

The available statistics supply us with the number of places for animals in each commune. In order to estimate the stock of farm fertilizers produced over a year, for each kind of husbandry three quantitative variables must be known: i) daily production of effluents per animal; ii) the number of days in a cycle of production, and iii) the number of annual production cycles for each kind of livestock operation. Table 1 summarizes the hypotheses used for the first variable; the paragraphs that follow give details of the hypotheses in relation to the production cycles.

Pig farm – We have used the number of sows as an indicator of the communal pig herds; to obtain the number of pigs raised yearly, an average technical itinerary should be defined. Most pigs in the study area are F1 pigs, crossbred from local Mong Cai sows with exotic young boars, Landrace or Large White. Table 2 presents the performances of an "average" NS (nursing sow). It is considered that pigs are fattened for the local market up to 75-80kg, and that the flows of piglets and pigs (from 8 to 45kg live weight) inputs and outputs from communes balance each other out. In addition, it can be estimated that 95% of faeces are scraped, as opposed to only 60% of urine. All the rest is evacuated by cleaning water. The quantity of water used has been estimated elsewhere (see Chapter 7): an average of 20 litres per day and per fattening pig (the same for a sow), from March to October. The rest of the year, the temperatures being lower, it is assumed that pigs are washed only once every three days. All of this information taken together makes it possible to evaluate the quantity of effluents produced per NS (nursing sow) and per year.

Other livestock farms – Most poultry farms in the study area fatten their stock. Broiler chicken farmers conduct 4 to 5 cycles of 50 to 60 days per year. For ducks, fattening takes longer, up to 90 days, and the number of cycles reduces in consequence, 3 to 4 cycles yearly. Cattle and water buffalo herds are mostly made up of animals for milking, the females (most animals) giving birth once a year on average. For the purpose of calculation, it is assumed that an adult cow weighs 250 kg (300 kg for a buffalo), and that calves are sold at 80 kg, at an age of 80 days.

Equivalence between solid excreta and composts

The following step consists of estimating compost production based on the quantities of solid effluents estimated above. Table 7 presents the different characteristics of composts encountered in the study area. By default, we consider that the loss of weight that accompanies composting is identical for all mixtures, and comes to 50% of the initial weight of the mixture (value measured in Le Van Can's experiment, 1975 (5)). The losses of weight that may take place during storage of solid effluents are not taken into account, as the two operations take place concurrently.

Table 1: *Farmers' behaviour concerning organic matter management*

Kind of farm	*Effluent*	*Daily production*	*Source*
Pigs	*Slurry*	*7 % of live weight [1]*	*(6)*
Sows	*Slurry*	*5% of live weight*	*(6)*
Broiler chickens	*Droppings*	*40 g*	*(7)*
Broiler ducks	*Droppings*	*40 g*	*(7)*
Cows, buffaloes	*Scraped slurry*	*7.5% of live weight*	*(8)*
Adult humans	*Solid excreta*	*0.13 kg*	*(5)*
	Urine	*1.2 kg*	*(5)*

[1] Made up of 54% faeces, and 46% urine (9).

Table 2: *Characteristics of a local NS (nursing sow) (10)*

Variable	*Value used*
# weaned pigs per litter	*8.25*
# litters per year	*2*
Average daily weight gain	*500 g*
Weight at slaughter	*75 kg*
Weight of a local sow	*90 kg*

Table 3: *Composition of mixtures before composting for various kinds of solid effluents*

Kind of farm	*% Effluent*	*Composting time*	*Materials added*
Scraped pork slurry	*70*	***3 to 4 months***	*Rice stalks, various crop waste*
Scraped cow slurry	*70*	***Idem***	*Idem*
Poultry droppings	*70*	***2 to 3 months***	*Rice husks*
Human excreta	*70*	***3 to 4 months***	*Rice stalk ashes*

Nitrogen and phosphorus content in farm fertilizers

Knowledge of the nitrogen and/or phosphorus content of the various livestock effluents produced in the study area makes it possible to convert quantities of farm fertilizers into quantities of nutrients. These values are indispensable for comparing effluents stocks coming from the various kinds of livestock farms in an objective manner. To this day, no analysis of farm fertilizers produced in Thai Binh is available. Other analytical data have been obtained during the project (see Chapter 7). About thirty analyses have been collected together from the Vietnamese or South Asian bibliography. We have used average values presented in Table 4 (we have assumed that the nitrogen and phosphorus content of scraped buffalo slurry are the same as for cows). These average values can vary depending on the dry matter content of products.

Table 4: *nitrogen and phosphorus content in farm effluents (in % of fresh weight)*

Animals	*Effluent*	*% N*	*% P2O5*	*Source*
Pigs	*Scraped slurry*	*0.7*	*0.46*	*1*
	Urine	*0.5*	*-*	*2*
	Compost	*0.66*	*0.77*	*2*
	Cleaning water	*0.037*	*-*	*3*
Poultry	*Chicken droppings*	*1.6*	*1.2*	*1*
	Duck droppings	*0.55*	*-*	*2*
	Chicken compost	*1.5*	*1.8*	*3*
Cows	*Scraped slurry*	*0.3*	*0.23*	*1*
	Compost	*0.6*	*0.57*	*2*
Humans	*Excreta*	*1.1*	*0.46*	*2*
	Compost	*0.92*	*1.3*	*3*

Sources: (1) Dierolf, 2001. (2) Le Van Can, 1975. (3) Mass calculation: when no analysis was available, we made mass calculation. At the time of composting, losses in nitrogen were estimated to be 40% of the initial quantity of nitrogen (5).

Box 1: Production of nitrogen by one local nursing sow (NS)

1 Local NS *produces about 73kg of nitrogen yearly, of which 75% go into solid excreta, and only 25% into liquid excreta.*
1 Local NS *produces about 7,600kg of scraped slurry yearly, or 5,400kg of compost, containing 36kg of nitrogen.*
1 t of nitrogen *from pig compost = 150 t of pig compost, produced by 80 local NS in one season = 11 "fertilizable" hectares of spring rice = 500 trips by bicycle (at 300kg per bicycle)*
1 t of nitrogen *from pig farm cleaning water = 2,700m3 of liquid effluents, produced by 50 local NS in one year = 12 fertilizable ha yearly*

Calculation of farm fertilizer quantities potentially usable by fish farm ponds

Locally, no study has been carried out on the capacities of an "average" pond to absorb various livestock effluents. We have therefore sought the references available in the bibliography; the results are presented in Table 5. The ratios indicated are given for farmed ponds according to the technical itineraries practised in the study area. This is extensive mixed farming of grass carp, with yields from 2 to 4 metric tons per hectare (the higher yields being obtained in the VAC system), and a stock density of 1.2 fish per square metre (11). These animal stock ratios are exclusive: one or another livestock production unit can be linked to a pond, but linking several kinds of livestock unit at the same time is not dealt with here. Through lack of references, we have calculated cattle stock levels from recommendations given for pigs. We therefore arrive at a ratio of six cows or buffaloes per hectare of pond.

Table 5: *Animal stock ratios (number of places) per hectare of pond*

Kind of livestock	*Animal stock/ha of pond*	*Source*
Ducks	*300 ducks*	*Tripathi, 2003 (FAO)*
Pigs	*60 pigs*	*Huyen, pers. com.*
	66 pigs	*Fermin, 1966 (FAO)*
	60 pigs	*(11)*
Chickens and hens	*300 to 500 birds*	*Gupta, 2003 (FAO)*

Calculation of quantities of farm fertilizer potentially usable by crops and gardens

To calculate the consumption capacity of farm fertilizers by crops, we will develop two complementary approaches:

1. an approach integrating local organic fertilization advice that we will call the **recommendations approach**. This approach will easily be understandable by the local partners, which can in theory increase the credibility that they give to the results.
2. an approach that employs the principles of "reasoned" fertilization that we will call the **theoretical approach**: organic fertilizers are integrated into a fertilization calculation taking into account the soil's nutrient supply and the efficiency of the fertilizers. This approach is for the use in particular of local scientific partners, and is limited to annual crops.

Box 2: Organic fertilizer and organic enriching agent

Fertilizer: *substance whose main function is to provide plants with one or several nutrients (French Standard NF X 31-006. Terminology associated with fertilization. October 2000).*
Enriching agent: *mineral or organic substances whose purpose is to maintain or improve the physical and/or chemical properties and/or biological activity of soils (French Standard NF X 31-006).*
The frontier between these two definitions is often difficult to establish. Manures and composts are traditionally defined as organic enriching agents in France, owing to their modest direct effect, although the long-term effects that they engender can be significant. However, the study area's temperature and humidity conditions lead one to conclude that the mineralization of organic matter contained in farm fertilizer is much more rapid than in French climates. The proportion of organic nitrogen mineralized during a crop cycle could increase accordingly. Paddy field soil in the province has a carbon/nitrogen ratio (C/N) of about 7, a sign of intense biological activity, which is expressed by a rapid decomposition of organic matter. In addition, some farmers habitually practise "opportunist" spreading of compost on their rice two months after sowing, a practice that demonstrates the role of organic fertilizer that is implicitly associated with it. For these reasons, we will not classify the farm fertilizers encountered in Thai Binh into fertilizers or enriching agents (the local agricultural offices themselves make no distinction). The common denominator used to compare quantities of different composts will be nitrogen, which we assume to be the element limiting the yield of the crops under consideration.

Approach based on local organic fertilization recommendations, recommendations approach

Annual crops - Local organic fertilization recommendations are limited (see Chapter 8). The main restriction to their understanding is the vocabulary used: dosages to be applied are given for *phan chuong*, term that signifies either scraped slurry, or the composted mixture of this slurry with plant waste. In this study, when *phan chuong* was encountered in Vietnamese documents, it has been translated as pig or cow compost, which remains the most widespread understanding of this term. Table 6 summarizes the dosages adopted for the calculation of balances in local units (kg per sao) and in metric tons per hectare. For chicken and duck composts (with higher nitrogen levels), we have assumed that the dosage to be applied is 60% of recommended dosages for pig compost. For human compost, a flat rate of 200kg per sao (i.e. 6 metric tons/ha) has been set by default. It corresponds to dosages practised by farmers on vegetables and leguminous plants (see Chapter 8).

Table 6: *Recommendations for organic fertilization (5, 12)*

Crop	*kg/sao*	*t/ha*	*Source*
Spring rice	*500*	*14*	*1,2*
Summer rice	*500*	*14*	*1,2*
Vegetables	*1,080*	*30*	*2*
Maize	*600*	*17*	*1*
Soya	*360*	*10*	*2*
Sweet potato	*700*	*19*	*1*
Potato	*700*	*19*	*1*
Groundnut	*700*	*19*	*1*
Beans	*720*	*20*	*2*
Cucurbitaceae	*2,161*	*60*	*2*

Perennial crops – Only the mulberry bush is considered here. We have adopted the advice of the Vu Thu Mulberry Scientific Institute, which recommends an annual application of 9 metric tons per hectare of pig or cow compost, to be applied in December. The application of compost before plantation is not taken into account, because it entails small quantities (5 metric tons per hectare), over long periods of time; the useful life of a bush being 10 years.

Gardens – In the communal model used, let us repeat that the "average" garden in the study area contains perennial plants – mostly medicinal plants (*Sophora japonica*) -, fertilized exclusively with liquid pig effluents. There are no recommendations in existence for this kind of fertilization. We therefore follow the farmers' practices, namely 10 litres per plant and per week of liquid effluents (see Chapter 8). The number of plants per hectare of gardens is estimated thanks to advice given by the agricultural offices, that advise a spacing of 6x8 metres between seedlings when planted. According to these elements, a sao of "average" garden can receive 150 litres per week, or about 4m3 per week and per hectare. We assume that irrigation by the bucket-load is carried out all year round.

Approach based on the principles of "reasoned" fertilization, theoretical approach

A definition of reasoned fertilization was proposed by the Comifer (French Committee for the Study and Development of Reasoned Fertilization) in 1992 (6): "Reasoned fertilization is the totality of practical and agronomic rules i) that are organized according to a coherent logic from the double standpoint of the farmer (who acts) and the agronomist (who advises); and ii) that enables the farm manager to inform his choices with regard to application of mineral and organic fertilizers with a view to achieving the quantitative and qualitative production targets that he sets himself within the framework of the cropping system and the soil and climate potentialities within which he operates while preserving, or even improving, the ecological characteristics of that given environment." The aim of this approach is therefore to determine the quantity of mineral elements to be applied to a crop with a view to obtaining an expected yield, while limiting the risks of pollution from excess nitrogen or phosphorous. The dosages of elements applied must compensate for elements lost, assumed to be proportional to the yield targeted by the farmer, taking into account the supply of mineral elements in the soil. We call this a provisional balance.

To calculate fertilization with nitrogen, two equations exist: i) the nitrogen mass balance equation that gives between two dates the mineral nitrogen contained in a layer of soil of a set thickness. This balance integrates all of the factors that come into play in the dynamic of mineral and organic nitrogen: process of volatilization and denitrification and other losses, mineralization of organic nitrogen in the soil and of crop waste, etc.; ii) the equation of nitrogen efficiency that is not a balance in the strictest sense. This mode of calculation is based on non-fertilized controls (estimate of the effective supply of nitrogen by the soil), and ratios of nitrogen efficiency, measured experimentally.

We chose to use the nitrogen efficiency equation owing to the absence of reliable data making it possible to inform a mass balance. The experimental data available only make it possible to develop the fertilization calculations for rice. But the interest of such an approach for the project, in particular for the scientific partners, justifies that we retain it: it is original and makes it possible to widen the thinking on the reasoned use of locally produced farm fertilizers.

Box 3: Equation of nitrogen efficiency and integration of farm fertilizers into the calculation of reasoned fertilization

In a desire for clarity, we present the equation and the steps in the calculation of fertilization in the case of fertilization with nitrogen (the calculation of fertilization with phosphorous is based on the same principles). The equation of nitrogen efficiency, in the case of an exclusively mineral fertilization, is formulated as follows (13):

$$Nf = No + (CAU \times X) \qquad \textbf{\textit{Equation 1}}$$

Nf: total needs of the plant population, which depends on the targeted yield (kgN/ha)
No: quantity of nitrogen absorbed by an unfertilized crop (kgN/ha)
X: quantity of nitrogen (mineral) provided by mineral fertilizer (kgN/ha)
*CAU: apparent **mineral nitrogen** use ratio*
In the case of a mixed fertilization (mineral and organic), equation 1 becomes equation 2:

$$Nf = No + (CAU \times X) + (CAUo \times Xo) \qquad \textbf{\textit{Equation 2}}$$

Xo: total quantity of nitrogen (mineral and organic) originating from farm fertilizers (kg N/ha)
*CAUo: apparent **total nitrogen from farm fertilizers** use ratio (%)*
The apparent nitrogen use ratio estimates the efficiency of absorption of nitrogen contained in the fertilizer (mineral or organic) by the plant. Its value depends on the kind of plant, the soil type, the climate, fertilization practices and the kind of fertilizer considered.

Reasoning adopted to determine the dosage of farm fertilizer to be spread

The reasoning is done in 4 steps; it is given here to calculate fertilization with nitrogen:

1. Calculation of the quantity of nitrogen absorbed by the crop originating in mineral and organic fertilizers

It is necessary to determine the sum "CAU.X + CAUo.Xo", i.e. the difference "Nf – No" (cf. equation 2 above). One must therefore know:

- exports in the form of mineral elements of plants (Nf). For example, for rice, we set a yield of 8 and 6.5 metric tons per hectare, corresponding to exports of 157 and 106 kg of nitrogen per hectare for spring and summer rice respectively (Tran Thuc Son, n.d.).
- the supply from the soil (No). By default, we have taken the values obtained by Tran Thuc Son (14) at the time of trials carried out on rice in the Red River Delta over the last decade (Table 7).

Table 7: *supply of a Red River Delta alluvial soil in N, P, K (14)*

Nutrient	*Supply from the soil for spring rice (kg/ha)*	*Supply from the soil for summer rice (kg/ha)*
N	*54.6*	*57.9*
P	*18.6*	*20.2*
K	*82.5*	*66.4*

2. Evaluation of the maximum possible fraction originating from farm fertilizer

A substitution ratio of mineral nitrogen by nitrogen of organic origin (proportional to the ratio (Xo.CAUXo) ÷ (X.CAU)) is then defined. To our knowledge, no detailed study has been carried out on the way in which farmers in the Delta integrate the various mineral and organic fertilizers into the "reasoning" of their fertilization. According to the interviews that were carried out within the context of this study (see Chapter 8), some farmers adapt the quantity of mineral fertilizer used according to the dosage of compost spread at the beginning of the cycle for fear of causing the shedding of rice, in particular. We consider, arbitrarily, that one third of total nitrogen needs come from organic fertilizers (this value is set at 100% for phosphorous).

3. Calculation of the dosage of farm fertilizer to be applied

The quantity of nitrogen originating from farm fertilizer absorbed by the crop (Xo.CAUo) is then converted into a total quantity of nitrogen provided by the farm fertilizer, via the apparent nitrogen use ratio; Table 8 presents the values used. The values found are given for farmyard manure (FYM), i.e. the product of traditional composting techniques. We pose two hypotheses: i) CAUs are the same for the four kinds of compost considered (human, pig, poultry or cow); and ii) the name given to them in English ("N use efficiency") implicitly signifies the relationship (Nf-No) ÷ Xo. The total quantity of nitrogen in farm fertilizer for spreading can then be converted into a quantity of compost, via the concentrations of nitrogen.

Table 8: *CAUs chosen for the calculation of reasoned fertilization (%)*

Element	***Spring***	***Summer***
N	*35*	*60*
P	*60*	*60*

4. Choice of dosage in relation to the most limiting element for reducing the risk of pollution

The calculations of fertilization with nitrogen and phosphorous, carried out according to the same method, give different quantities of compost to be applied. The smaller of the two quantities of compost is chosen, to avoid using quantities of nitrogen or phosphorous greater than needed. The calculation also makes it possible to determine the supplementary dosage(s) of mineral fertilizer(s) (with nitrogen and/or phosphorous) to be spread on crops.

Arbitration rules for allocation of effluents to crops

We have presented the methods making it possible to quantify, at the communal level, the production of farm fertilizer on the one hand, and the potential demand of consumption areas (crops, ponds and gardens) on the other. This demand is variable depending on the kind of farm fertilizer considered (liquid or solid effluents, pig or poultry compost, etc.) and the kind of usage (pond or crop, vegetables or rice, etc.). Couples (farm fertilizer) x (crops) have been defined when modelling of the commune took place (cf. Figure 2). Table 9 summarizes the main arbitration rules of allocation selected.

Table 9: *Couples (crops) x (farm fertilizer) and arbitration rules between crops*

Consumption area	***Usable farm fertilizers, arranged by order of priority***
Ponds	*Livestock effluents from: ducks > pigs > chickens > cows & buffaloes*
Gardens	*Liquid pig effluents*
Annual crops	*Human compost > poultry compost > pig compost > cow & buffalo compost*
Perennial crops	*Pig compost > cow & buffalo compost*

We have considered that livestock effluents were used in priority in ponds, for the following reasons: i) Ponds are generally located closer to livestock farms than are cultivated fields; ii) The direct transfer of the entirety of effluents into a pond remains the cheapest way of recycling them (see Chapter 6); we can therefore consider that this takes priority over both crops and gardens. The two other consumption areas (gardens and cultivated fields) are not in competition, because they do not receive the same effluents (cleaning water or compost, respectively). Ponds take precedence in receiving duck droppings, because keeping ducks is often associated with fish farming. Farmers generally use poultry droppings for crops in preference; they are therefore rated below pig slurry (Table 9). Scraped cow and buffalo slurry, which is of mediocre quality, are rated the lowest. The arbitration rules between crops regulating the transfers of composts onto crops, that is the order in which crops receive farm fertilizers, is established in two ways: (1) depending on the competition between several kinds of composts, linked to their content levels in nutrients, then (2) between several kinds of receptor crops depending on the habits of farmers, the nitrogen needs of plants, the kind of speculation and the proximity of dwellings to fields. The arbitration rules used are as follows:

- For pig, cow and buffalo composts: perennial plants > cucurbitaceae > vegetables > other dry crops > rice > leguminous plants
- For chicken compost: cucurbitaceae > leguminous plants > other dry crops > rice > leguminous plants
- For human compost: cucurbitaceae > vegetables > leguminous plants > other dry crops > rice

The “other dry crops” are maize, sweet potatoes and potatoes. The leguminous plants are groundnut, various kinds of bean and soya. These arbitration rules make it possible to allocate the various farm fertilizers to various consumption areas. Once these transfers have been carried out, we can then calculate a balance, representative of the level of livestock effluents saturation in communes.

Calculation of the adequacy between the supply of farm fertilizer and the demand for crops and fish farm ponds

Within each commune, the balances are calculated for use in each specified livestock effluents consumption area: ponds, gardens and cultivated fields (Figure 3). Each balance is defined as the difference between supply and demand of livestock effluents with relation to the consumption area in question. Here we are situated in the case of the approach labelled “recommendations”.

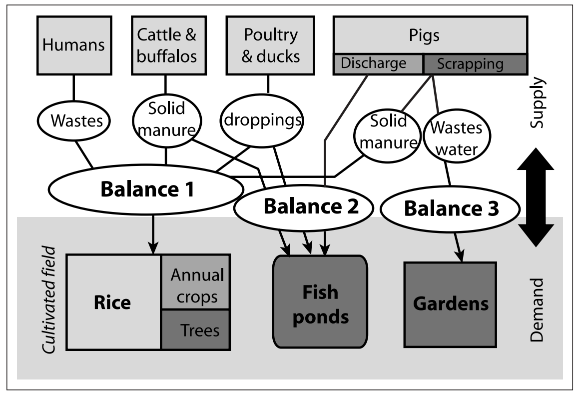

Figure 2: *Calculation of balances by kind of consumption area (AP: annual plants, PP: perennial plants)*

The period under consideration for the transfers of farm fertilizers, and the calculation of associated balances, depends on the operation under consideration: i) for gardens and ponds, the calculations of balances will be carried out for one year. We ignore the period during which the ponds are drained (the coldest time of year); ii) for annual crops, we will calculate the balances per season (spring, summer, winter). Let us note that to calculate a balance for a full season entails assuming that the production of solid effluents, and the associated operations of composting, are carried out regularly throughout the year, and in synch with the crop cycles; iii) perennial crops are integrated into the balance calculation of the season that corresponds to the time of year when they are fertilized (in winter for mulberry bushes).

To define the equations, we therefore set ourselves as a rule to test the capabilities of each consumption area to reabsorb livestock effluents, beginning by allocating effluents to ponds, in accordance with the order given above. Different situations can occur; let us take the example of the balance calculation on a field of rice: all the area planted with rice can be fertilized, and a stock made of unused compost(s) (positive balance). In this case, the remaining quantities of compost (and the corresponding quantities of nitrogen) are known. The balance can be easily calculated. The area cultivated with rice cannot be wholly fertilized by livestock effluents (negative balance). In this case, it is necessary to choose one or other of the kinds of compost to calculate the balance in livestock effluents.

The project of which this study forms a part being centred on the development of pig production, we have decided to calculate all the deficits in pig equivalents (local nursing sow (NS) equivalent). For example, one hectare of unfertilized rice in a commune will be equivalent to a balance of -14 metric tons of pig compost. We can calculate the equivalent in metric tons of nitrogen, by using the references established previously. For gardens, only liquid pig farm effluents are used; the calculation of the balance is therefore done directly, by comparing the supply and the demand in liquid effluents. Table 10 summarizes the equations enabling the calculation of the various balances.

The theoretical approach being limited to the calculation of the fertilization of rice, the calculation of balances will be carried out in the same way as for the "recommendations" approach. More detailed work on this path would have made it possible to calculate more objective balances in nitrogen or in phosphorous than those used here, in particular concerning deficits: a balance would have been defined by the equation: "(production of nitrogen or phosphorous) – (theoretical demand for nitrogen or phosphorous)".

Table 10: *Equations used for the calculation of balances (at the communal level)*

Consumption areas	***Period***	***Unit***	***Equation***	***Deficit calculation***
Ponds	*Year*	*Herd*	*S1 = herd present – "absorbable" herd*	*Number of NS*
Gardens	*Year*	*m^3 cleaning water*	*S2 = liquid effluents produced – usable liquid effluents*	*m^3 liquid pig effluents*
Crops	*Season*	*Metric t of compost*	*S3 = compost produced – demand for compost*	*Pig compost*

Development scenarios

We have imagined two future scenarios. In addition to changes in the animal herd, one must also integrate possible changes in the kind of crop rotation (crops likely to be developed), and of the kind of land use. These changes have been calculated on the basis of the planned changes in Vu Thu district. The results that will come out of these scenarios are not representative of all the districts in the province. They must be widely discussed with the stakeholders of Vietnamese agricultural policy and specified according to the elements of invalidation or validation that we later obtain. We therefore give percentages of change between 2004 and 2010 for each element of statistical data collected, in order to create a new projected set of statistical data for 2010. We then carry out the process explained above once again (carried out for 2004).

Changes in land use - Table 11 summarizes all the changes likely to occur between now and 2010. Land use is thus subject to many factors: i) An increase in fish farming capacity, a consequence of the conversion of low-lying paddy fields into ponds, and the farming of bodies of water currently not yet in use; ii) An increase in the land occupied by dwellings (demographic growth), which leads to a decrease in the size of gardens; iii) An increase in the size of the population manifests itself by an increase in public infrastructure, which would normally be built on as yet unused land.

Changes in crop rotation - Figure 4 illustrates the projected changes in crop rotation by season in Thai Binh province, in comparison with the rotation for 2004. This projection initially established for Vu Thu district has been extrapolated to all the districts in the province. The document produced by Vu Thu agricultural department is based on the figures for the year 2005, while the statistical data on crop rotation used are from 2004; after verification, the bias generated is negligible. The difference in area of each kind of crop makes it possible to give a percentage of change. This is then applied uniformly to the communal statistical data from 2004 for each season, in order to obtain a projection of crop rotation in 2010.

Table 11: *Change of land use from 2004 to 2010*

Land use	2004	2010	Difference	%
Crops	211,704	198,736	-12,968	-6
Ponds	8,952	13,900	4,948	55
Gardens	6,182	5,032	-1,150	-18
Public infrastructure	n.a.	n.a.	n.a.	14
Dwellings	n.a.	n.a.	n.a.	7
Fallow land	65,592	51,162	-14,430	-22

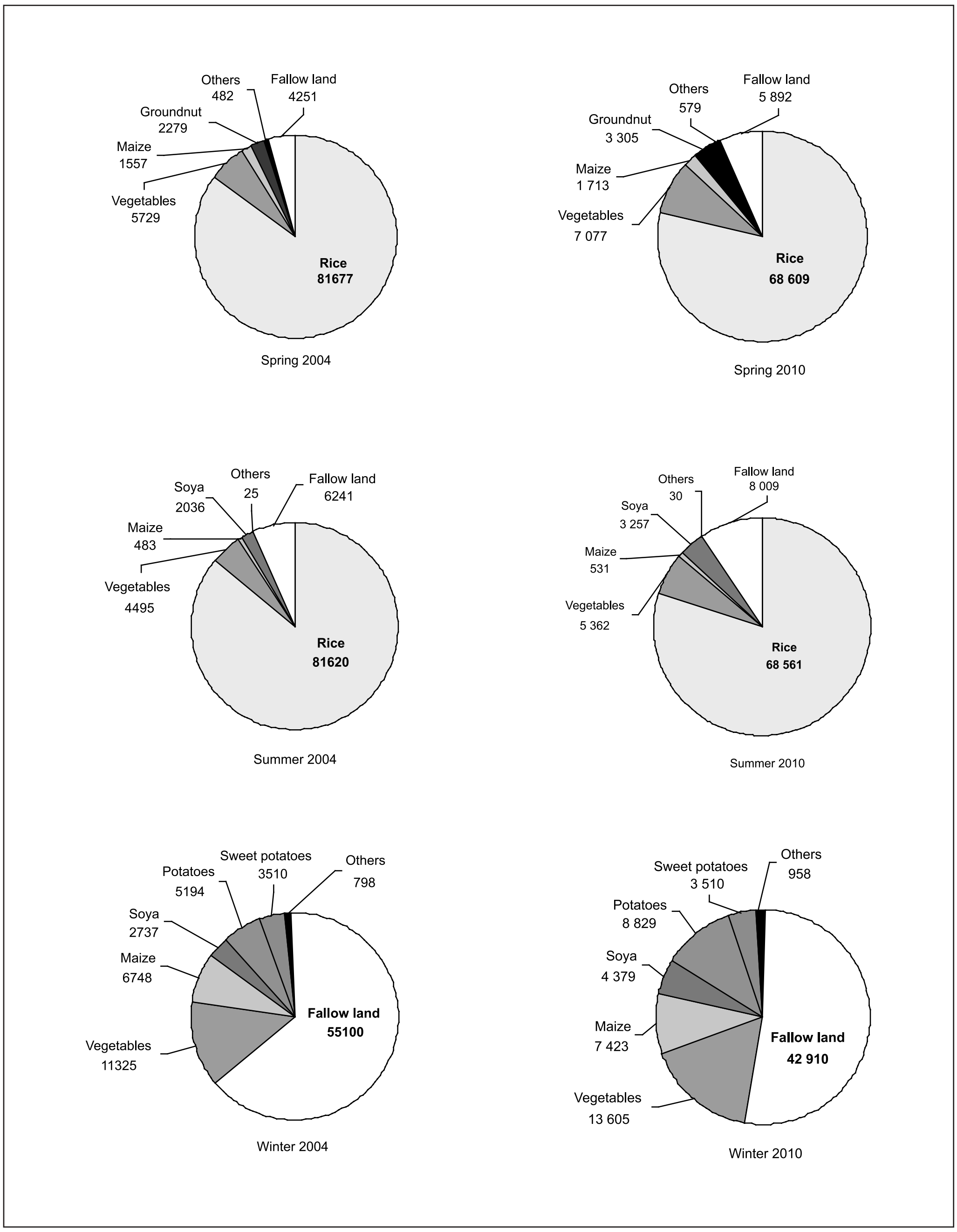

Figure 3: *Seasonal crop rotation in Thai Binh province in 2004 and in 2010*

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***Table 12:** Potential change in the herd in Thai Binh province from 2004 to 2010*

Category	*2004*	*Objective 2010*
NS	*208,529*	*282,000*
Poultry	*17,588,460*	*58,000,000*
Cows	*66,959*	*86,000*
Buffaloes	*8,443*	*11,600*

Organization of the database and spatializing of results - Figure 5 illustrates how the database works. The statistical data and the calculation parameters are entered with Excel 2004. Using commands such as “IF (expression of condition) THEN (equations of calculation)”, various farm fertilizers are allocated to various consumption areas. The condition "IF" makes it possible to identify a deficit or surplus farm fertilizer situation, and consequently choose the mode of livestock effluents balance calculation.

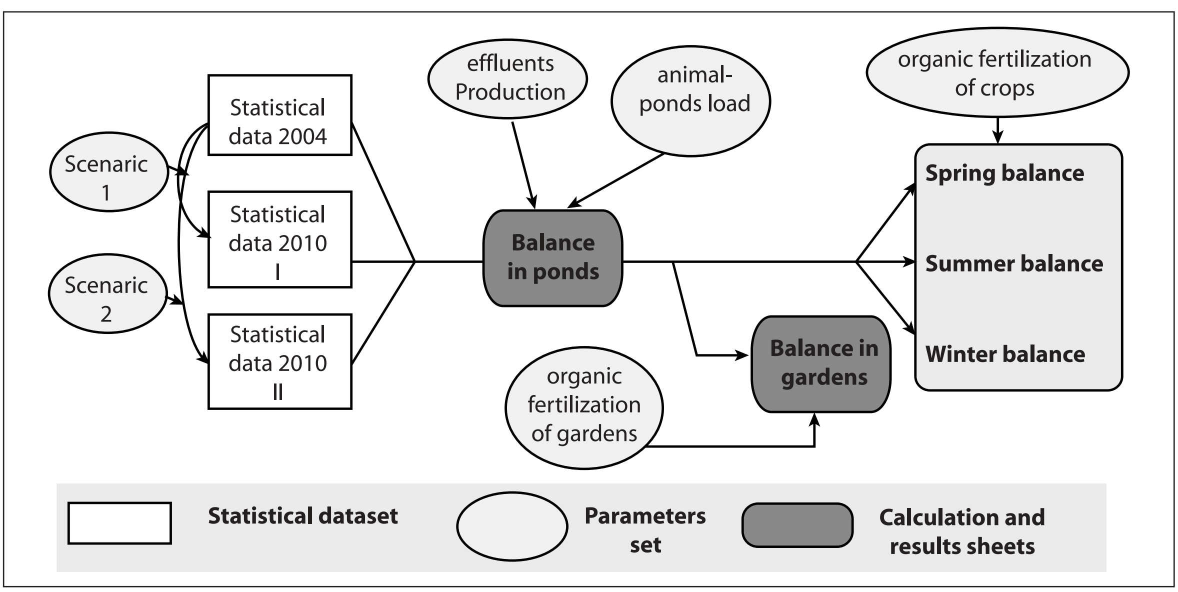


***Figure 4:** Tool for calculating livestock effluents balances*

The database makes it possible to calculate livestock effluents balances (output), from input data. It is organized into four groups of sheets: 1) one sheet containing all the communal statistical data for the year 2004: area of ponds, area of gardens, area of crops by season, animal herd, population; 2) parameter sheets, relative to farm fertilizer production (raw effluents, equivalencies with quantities of compost), to organic crop fertilization, to animal stock/pond area ratios, and finally parameters making it possible to create scenarios 1 and 2; 3) calculation sheets, whose structure is identical for the years 2004 and 2010, and for the two scenarios envisaged; 4) results sheets, showing balances by commune and for the various kinds of consumption areas (ponds, gardens, crops). The balances calculated with Excel for the 285 communes are linked to an Excel file that synthesizes the results. This is then imported into MapInfo 7.0, and coupled with the administrative divisions (communal level) taken from the digital atlas of Vietnam (2004). Thematic maps are generated in this way, illustrating the various approaches and scenarios developed.

Results

In this final section, we present firstly the results of calculations of balances obtained according to the "recommendations" approach, in 2004 and in 2010, according to the two scenarios (i.e. (1) uniform distribution of the herd over all the communes and (2) distribution of the herd according to the communal specialization plans). Secondly, we briefly compare the results obtained with the more refined theoretical approach developed for calculations of rice fertilization. The "overall balance" of the study area is defined as the sum of the balances of the 285 communes in Thai Binh province.

Current and future adequacy between supply and demand of livestock effluents in Thai Binh province

The quantification of the stock of effluents produced ("supply of farm fertilizer") enables the establishment of a hierarchy of importance of various farm fertilizers in the study area; this is the first result of this work. Then, the current balances of livestock effluents, and their change over the five following years will be presented and commented for each kind of consumption area: fish farm ponds, gardens and crops for different seasons.

Estimate of livestock effluents supply in the study area

The method established makes it possible to estimate the quantities of effluents produced annually in the province and each of the districts. Table 13 summarizes the results obtained, by quantity of raw excreta and by quantity of nitrogen. It should be noted that pig production generates the greatest stock of solid effluents, both in terms of quantities of raw effluents and of nitrogen. It represents about 70% of the nitrogen produced in 2004. The increase in production of chicken droppings was very great; the deposit of nitrogen engendered should in 2010 reach half the size of that engendered by scraped pork slurry. Liquid pig effluents represent a considerable volume, which could increase 35% by 2010. The corresponding quantities of nitrogen are significant, on the same scale as the nitrogen produced by human excreta. The proportion of nitrogen (contained in solid excreta) produced by the pig herd and the chicken flock in 2004 is 58%. In 2010, it will be 64% of a potential deposit of almost 36,000 metric tons of nitrogen of animal and human origin produced yearly in Thai Binh province.

Table 13: *Supply of livestock effluents in Thai Binh province (metric tons of effluents and metric tons of nitrogen per year)*

	Year	*Scraped pig slurry*	*Chicken droppings*	*Duck droppings*	*Scraped cow slurry*	*Human excreta*	*Liquid pig effluents*
Raw effluents	*2004*	*1,591,822*	*146,139*	*31,661*	*527,590*	*357,713*	*11,291,845*
	2010	*2,152,668*	*481,912*	*104,407*	*683,828*	*371,898*	*15,270,300*
Nitrogen	*2004*	*11,143*	*2,382*	*317*	*1,583*	*3,935*	*4,147*
	2010	*15,069*	*7,855*	*1,044*	*2,051*	*4,091*	*5,608*

Mass balance of farm fertilizers for use in fish farm ponds
The cartographic illustrations are presented in Plate 2.
In 2004 – Almost all communes have too much livestock effluents to fertilize their ponds. If the ponds were the only potential farm fertilizer consumption areas the surpluses would amount to 16,100 metric tons of nitrogen over the whole province. Ten communes do not have enough effluents to fertilize their ponds. These communes are located in the districts of Thai Thuy where the fish farming specialization is very marked (6), Tien Hai (3) and Vu Thu (1). At the provincial level, 31% of total nitrogen from farm fertilizer can be put to use in the ponds. The ponds therefore represent a significant consumption area for farm fertilizer.

In 2010 **–** We see a growth in surpluses in the communes that already had surplus production in 2004. Over the whole province, Scenario 1 would give a surplus balance of 27,641 metric tons of nitrogen per year; practically the same as that of Scenario 2 which would be about 27,073 metric tons of nitrogen per year. Overall, in 2010 and whatever the scenario, fish farming ponds will only be able to absorb 22% of the total nitrogen from farm fertilizer; this despite the significant increase in these ponds.

Mass balance of farm fertilizers for use on gardens
The cartographic illustrations are presented in Plate 3.

In 2004 - Only liquid excreta are spread onto gardens. Few communes have a shortfall, 16 out of 285. The other communes have a surplus, but most of them (246) have quite small surpluses. 23 communes produce surplus nitrogen of more than 25 metric tons per year. Depending on the specialization plans to be adopted by these communes, they will have to deal with pollution risks caused by liquid pig excreta. Today, 22% of the nitrogen from liquid excreta is consumed by gardens. At the provincial level, the surplus nitrogen associated with the non-consumption of liquid excreta and cleaning water represents 3,234 metric tons.

In 2010 - The projected situation in 2010 is getting worse with an increase in the quantity of nitrogen produced by liquid excreta and cleaning water of 35%. Most communes will have a surplus; 6 communes will still have a shortfall. Some communes for which no specialization plan for pig production has been made will even so have surpluses, while others for which a specialization plan has indeed been made will not. Only 14% of the nitrogen from liquid excreta will be consumed by gardens in both scenarios. Liquid excreta and cleaning water being recycled only in gardens to feed fruit trees, the associated environmental risk is high given the low level of absorption of this consumption area. Plate 3 presents the mass balance for use of liquid excreta and cleaning water. At the provincial level, the excess nitrogen associated with the non-consumption of this liquid excreta and cleaning water will increase in relation to 2004; in 2010, it will represent 4,815 metric tons and 4,706 metric tons respectively for Scenario 1 and for Scenario 2. The difference between Scenarios 1 and 2 derives from the number of communes with a surplus balance over 25 metric tons. This comes to 107 communes in Scenario 2 while it only amounts to 71 in Scenario 1.

Mass balance for use of farm fertilizers on crops
Table 14 presents the overall mass balances for the three seasons (spring, summer, winter) in 2004 and 2010. In 2004 the province's situation shows a shortfall (-3,565 tN). In 2010 on the other hand, whichever the scenario and whatever the season, the situation will clearly show a surplus for the whole province.

Table 14: *Overall mass balances calculated by season in 2004 and 2010 (tN)*

Year	*Scenario*	*Spring*	*Summer*	*Winter*
2004	*-*	*-2,974*	*-2,665*	*2,074*
2010	*1*	*388*	*786*	*3,612*
2010	*2*	*114*	*516*	*3,454*

Spring mass balance
The cartographic illustrations are presented in Plate 4.

In 2004 – Almost all the communes in the province (244) show a shortfall in the spring of 2004. Only 41 communes show a surplus of which 36 with a nitrogen surplus of between 0.1 and 25 metric tons of nitrogen. 5 communes have a surplus of between 25 and 309 metric tons of nitrogen (Quynh Phu, Thai Thuy Hung Ha districts).

In 2010 - The situation will be the opposite of 2004. Whichever scenario is used, the overall nitrogen mass balance in spring 2010 will show a surplus, with a surplus of 388 metric tons of nitrogen for Scenario 1 and 114 metric tons of nitrogen for Scenario 2. The significant increase in livestock productions will have to deal with a potential decrease in area of cultivated land of the order of 10,000ha over the whole province. Areas of land planted with rice will be decreasing rapidly. This decrease will not be compensated by an increase in land given over to producing vegetable cash crops. The surplus communes will be mainly located in the north of the province, particularly because the pig, cattle and poultry production specialization plans are concentrated in the north and northwest of the province.

Summer mass balance
The cartographic illustrations are presented in Plate 5.

In 2004 – The overall mass balance for the province shows a shortfall (2,665 tN); but it is higher than that obtained for spring. In fact, although the area planted with rice for these two seasons is the same (about. 81,600ha), the area used for vegetable cash crops decreases by more than 2,000ha, which are left lying fallow. There is surplus nitrogen production in 43 communes of which 7 surpluses of more than 25 metric tons of nitrogen per year.

In 2010 - The situation will be the opposite in 2010 at the provincial level, the mass balance showing a surplus whatever the scenario, with a surplus of 786 metric tons of nitrogen for Scenario 1 and 516 metric tons of nitrogen for Scenario 2. 11,000ha less land will be cultivated than in 2004; the loss of area planted with rice will not be compensated by areas given over to vegetable cash crops and areas lying fallow will increase significantly.

Winter mass balance
The cartographic illustrations are presented in Plate 6.

In 2004 - 241 communes show a surplus (2,074tN). These surpluses are closely linked to decreases in cultivated areas. No rice is grown during the winter. Land lying fallow represents almost 55,000ha. Consequently, only areas planted with vegetable cash crops can make use of livestock effluents.

In 2010 – The overall mass balance at the provincial level will still show a surplus which scenario is considered, with a surplus of 3,612 metric tons of nitrogen for Scenario 1 and 3,454 metric tons of nitrogen for Scenario 2. In both scenarios, 245 communes will show a surplus. The surplus seems to be contained by the increase in area planted with vegetable cash crops and the decrease in land lying fallow.

At this stage of the study, we can submit the following appraisal:

1. Fish farm ponds represent a significant consumption area for use of livestock effluents, but less so than crops. They have the advantage of absorbing both liquid and solid effluents.
2. Garden areas do not suffice to absorb all liquid pig effluents. Whichever scenario is imagined, the surpluses - already great in 200 - will increase by 2010. This production, in fact not being properly put to use, is very dangerous because of the high risk of chronic pollution that it causes or that it can cause.
3. In the spring and summer of 2004, most communes show a shortfall in farm fertilizers. In 2010, at the provincial level and whatever the season, there will be surpluses.
4. During the winter there are large inadequacies between the stock of farm fertilizers present at this time in communes, and the capability of crops the reabsorb them. Most communes have a positive mass balance in 2004. The situation in the future will be more or less the same for all communes but with an increase in surpluses.
5. The specialization plan for communes does not have a great impact on the balances of solid effluents, because it limits the number of specializations per commune. On the other hand, it accentuates the surpluses in liquid effluents in the communes specialized in pig production.

Given these results, the development of pig production and of other animal commodity chains could rapidly be questioned because of the difficulty of putting liquid excreta to good use for most communes in the province, and because this will probably become progressively more difficult as the years go by. The lack of potential areas for the recycling of solid excreta in winter in some communes will also probably become very rapidly problematic. The situation will probably reach saturation level for all communes around 2009-2010 if the development of animal production commodity chains continues at the rate we have used here. The surpluses observed in some communes are worrying however. The study area's very positive mass balance in winter suggests that transfers between communes constitute the best solution to be envisaged for communes with a surplus.

This gives rise to four key questions:

1. What future can be envisaged for liquid pig effluents, that gardens cannot absorb (direct discharge into watercourses, excessive dosages applied onto gardens, etc.)?
2. What future can be envisaged for solid livestock effluents in winter in the communes showing a surplus?
3. Given the diversity of situations encountered at the

communal level, how can the most "high-risk" communes be identified, both today and in the future?

4. What maximum herd sizes could Thai Binh province accommodate given its capacities for use of farm fertilizers as the year 2010 approaches?

It is unfortunately impossible to take this reasoning any further given the lack of precise information on the specialization plans, on animal and matter transfers between livestock farms and on the development modes of pig farms in particular.

Results obtained using the theoretical approach
For the reasons already mentioned in the methodology, the theoretical approach has been restricted to the calculation of fertilization for rice. The only parameters that change in the end are the quantities of farm fertilizer spread per hectare and per cycle of rice. There are therefore no consequences on the surpluses observed in winter, when only dry crops are grown. Based on these figures, balances of solid effluents in the spring and in the summer are higher, and a few communes have positive balances in the summer of 2004. We will not however embark upon a more detailed analysis of the results obtained, because the values of parameters used in the fertilization calculations are debatable. The main interest of this approach, at this stage, is the establishment of an innovative mode of fertilization calculation in Vietnam, presented in the following paragraph; this shows a possible constructive use of farm fertilizers.

The theoretical approach has produced "reasoned" fertilization integrating farm fertilizers. The results are shown in Table 15. Although farm fertilizers are used to supply the entirety of the phosphorous used up by plants (despite the fact that only a third of nitrogen needs are provided in organic form), this appears to be a limiting element in the spring. In the summer, the levels of nitrogen used up by rice are clearly lower (decrease of 30% (14)) while the need for phosphorous remains identical, which has the effect of producing the opposite situation. Quantities of compost to be applied are clearly lower than the recommended dosages.

Table 15: *Calculations for mixed fertilization based on the equation of nitrogen efficiency*

	Spring rice				***Summer rice***			
Kind of compost	***Pig***	***Cow***	***Poultry***	***Human***	***Pig***	***Cow***	***Poultry***	***Human***
Qty of compost according to needs in N (t/ha)	*15*	*16*	*6*	*10*	*5*	*5*	*2*	*3*
Qty of compost according to needs in P (t/ha)	*7*	*10*	*3*	*7*	*8*	*10*	*3*	*7*
Qty of compost used (t/ha)	*7*	*10*	*3*	*7*	*5*	*5*	*2*	*3*
Qty of compost recommended[1] (t/ha)	*14*	*14*	*8*	*6*	*14*	*14*	*8*	*6*
Supplementary mineral N to be added (kg/ha)	*85*	*81*	*85*	*81*	*32*	*32*	*32*	*32*
P_2O_5 to be added[2] (kg/ha)	*0*	*0*	*0*	*0*	*13*	*17*	*12*	*17*

[1] Advice given by the Vu Thu Agricultural Department, or found in the bibliography.
[2] To be completely exact, this is nitrogen absorbed by plants and coming from mineral fertilizer.

Plate 1: *Specialization plans for pigs, cattles, poultry and fish for the communes of Thai Binh. In white are the communes for which no specialization is planned; in grey, Thai Thuy district for which the specialization data were not obtained.*

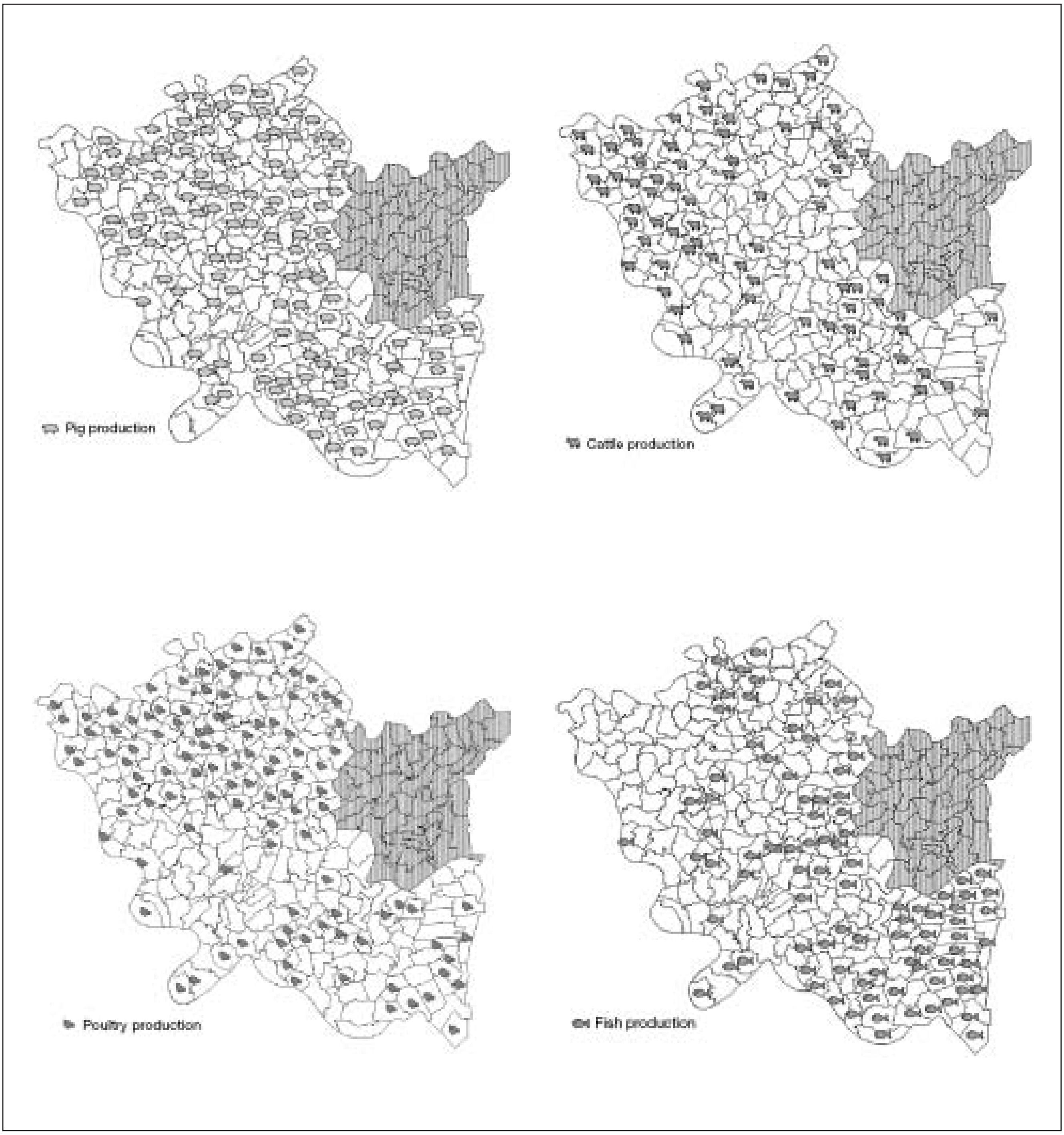


Plate 2: *Mass balance for use of farm fertilizers by fish farm ponds in Thai Binh (tN/commune)*

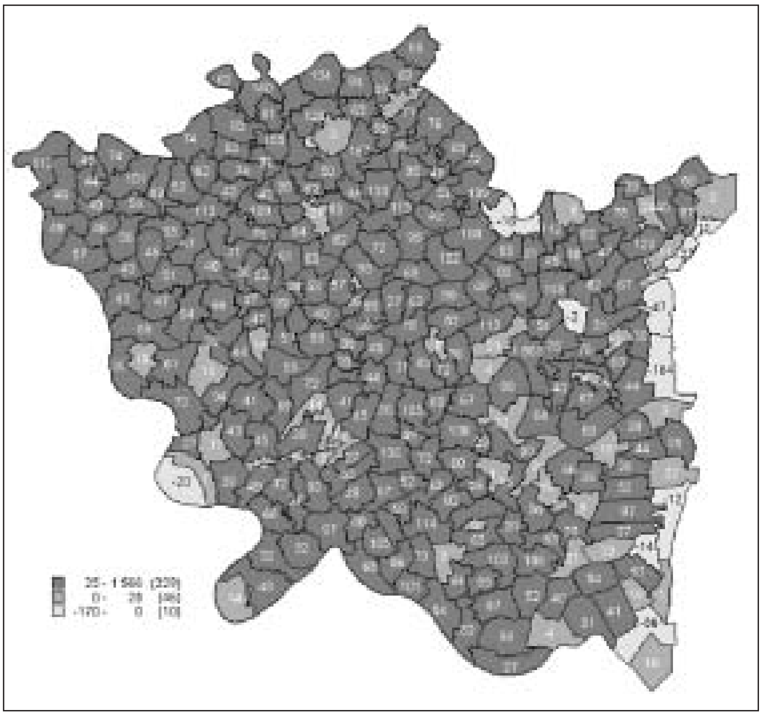


Plate 3: *Mass balance for use of farm fertilizers by gardens in Thai Binh (tN/commune)*

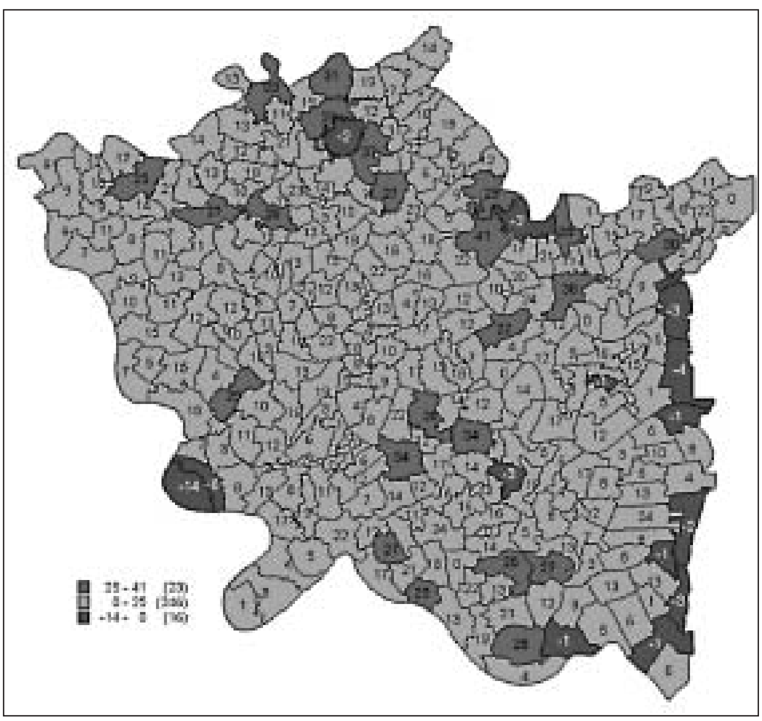


Plate 4: *Mass balance for use of farm fertilizers by crops in the spring in Thai Binh (tN/commune)*

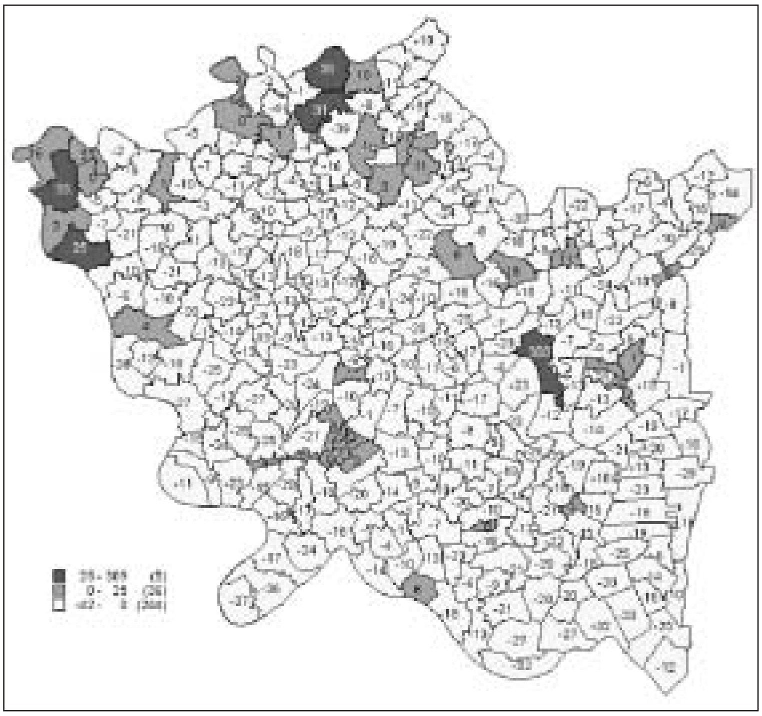


Plate 5: *Mass balance for use of farm fertilizers by crops in the summer in Thai Binh (tN/commune)*

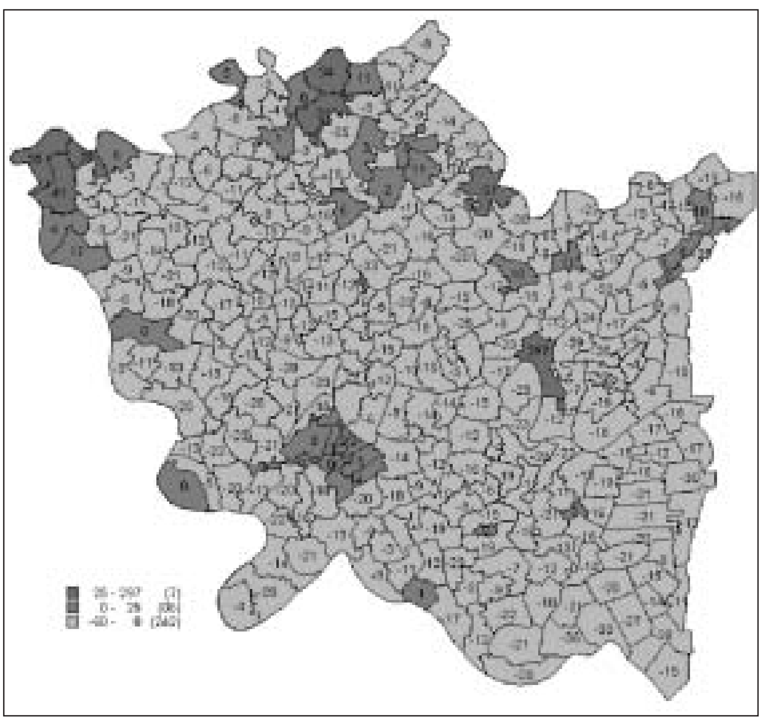
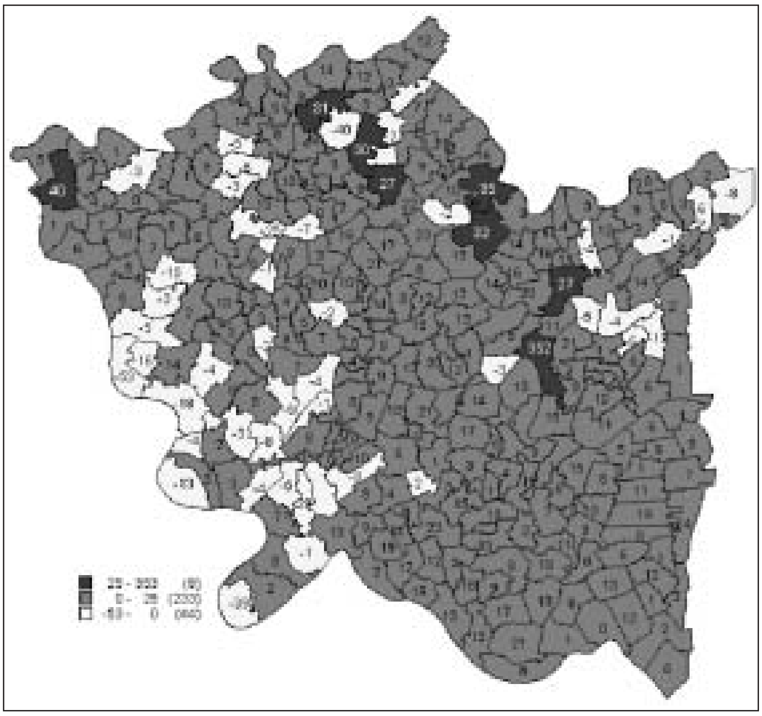


Plate 6: *Mass balance for use of farm fertilizers by crops in the winter in Thai Binh (tN/commune)*



Discussion

The first point that can be discussed concerns the accuracy of the quantitative results, which are difficult to judge both for the production of effluents and for mass balance, due to the lack of comparison with knowledge of the field by local political and agricultural development stakeholders. The objective for local stakeholders is to use the trends revealed by this study. For example, the trend observed for recycling of liquid excreta and that observed in winter for the recycling of composts showed strong risks of pollution, located particularly in the communes having mass balances with large surpluses. These trends have been confirmed in certain cases by field surveys conducted in Vu Thu district.

The second point of discussion concerns the mass balances calculation tool that has been developed and the methodology employed. The Excel spreadsheet has been endorsed by the local scientific partners in its first version, restricted to only Vu Thu district. We have extended it to the whole province using the hypothesis that the area for which it was developed is representative of what is observed province-wide.

Concerning the methodology, the choice of communal model can be questioned. The hypothesis of generalized practice of scraping in pig production units, in particular, can be questioned because it has an important influence on the balances. Surveys carried out within the framework of the AsiaProEco/E3P Project have shown that some farmers use small quantities of cleaning water, and produce their compost from the mixture of liquid and solid waste. This scraping hypothesis can also be debated for prospective scenarios; new buildings to be constructed are likely to be designed on the basis of Western industrial standards with floors made of metal grating and production of slurry. Our model could therefore underestimate the quantities of nitrogen available for crops, and overestimate the quantities of liquid effluents produced (which contain about a third of the total nitrogen discharged by pig farms).

Supposing that all fields are eligible for spreading is also a bold hypothesis, when we know that fields located far from villages do not systematically receive organic fertilizers (prohibitive costs of transport). These constraints vary according to communes (road system, topography, etc.), and only the localization of potential consumption areas would make it possible to include this component in the model.

The data concerning the pig herd appear to be the main limit to the statistical data used. The flows of piglets and adult pigs existing from one commune to another (see Chapters 2 and 5), that cannot be quantified, could bias the estimate of effluents supply in some communes. We should mention the case of communes specialized in sow breeding, which in fact do not fatten many pigs. The quality of other statistical data seems to be reasonably good.

In order to estimate the production of farm fertilizer, due to the absence of local references, we have often been obliged to use values from other regions, or to trust the estimates of local or Western experts. The main limits concern the levels of nitrogen and phosphorous in effluents (absence of measurements), and the estimate of volume of water used for cleaning pig farm buildings. This latter figure could be overestimated, but up until now no other measurement makes it possible to pursue this discussion further.

The theoretical approach is based on general data, sometimes concerned with Southeast Asia (e.g. the apparent nitrogen use ratio), and on references obtained in other provinces of the Delta (e.g. supply of nitrogen from the soil). Other references have been set arbitrarily (level of substitution of mineral nitrogen by nitrogen of organic origin), in the absence of local data. These are all potential avenues of research for local scientific institutes.

Finally, the accuracy of some parameters used for the creation of the 2010 scenarios, taken from official texts, is debatable. It may be wondered whether the projections made by Vu Thu district's People's Committee, and the agricultural departments, in terms of size of animal herd, are realist, upon inspection of some of these projections, such as the "planned" increase of + 230% in the number of poultry in 5 years while the avian influenza epizootic has affected this sector heavily.

Conclusion

Pig farm effluents may represent about three-quarters of the nitrogen discharged by all of the livestock farms in the area, and by humans. The complexity of the environment led us to calculate livestock effluent balances segment by segment – fish farm ponds, gardens and crops –, and according to various cycles – season or calendar year. It is possible to draw the following conclusions:

- In the chosen model, ponds represent an essential consumption area for use of liquid and solid effluents that in 2010 could absorb nearly a quarter of the total nitrogen from livestock effluents produced in the province.
- The development of the pork meat commodity chain could be compromised by the difficulty of putting liquid effluents to good use on gardens, the only potential consumption area considered in the model, which contains about a third of the nitrogen discharged by pig farms. There is an inadequacy between supply and demand, since barely 22% of the volume of liquid effluents produced can be recycled on gardens in 2004, then 14% in 2010. The rest (3,234 metric tons of nitrogen in 2004, about 4,800 metric tons in 2010) could be a large proportion of the polluting agents discharged into watercourses, a phenomenon observed in the field.
- The supply-demand adequacy in farm fertilizer on crops seems to be less problematic in the very short term, but the balance threatens to become a problem before 2010, with significant management difficulties in winter.
- The specialization plans decided on by districts seem to have had little impact on the balances of solid effluents, but they concentrate the surpluses in liquid effluents in the communes specialized in pig production.

The specified "model", validated by local experts, is an interesting tool. We have shown the various possible uses: in particular through the simulation of the situation in 2010. The limits attributable to this method are many, owing to the absence of diagnosis prior to this study, and of reliable data. The conclusions that can be drawn must not be considered as definitive. It is above all necessary to i) validate the parameters informing this "model" and ii) to compare the main trends revealed with the reality (large surpluses of liquid effluents, extreme situations of compost shortfall or surplus in winter).

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